Public Workshop on Lead-Acid Batteries and Alternatives

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California Department of Toxic Substance Control

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Primary Factors Considered

DTSC considers two primary factors when identifying a product-chemical combination:

1. Potential exposure to the chemical in the product

2. Potential for exposure to cause adverse impacts to human health or the environment

Primary Factor Considered:

1. Potential exposure to the chemical in the product

1. Legacy Sources
2. Minimal potential for consumer exposure
3. Minimal potential for environmental releases

Primary Factor Considered:

1. Potential exposure to the chemical in the product

1. Legacy Sources

- Lead exposures in California predominantly arise from historical use of leaded gasoline, paint, pipes, etc.

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Primary Factor Considered:

1. Potential exposure to the chemical in the product

2. Minimal potential for consumer exposure

- No clear pathway for consumer exposure to lead during product use

Primary Factor Considered:

1. Potential exposure to the chemical in the product

Batteries are enclosed in durable cases

Primary Factor Considered:

1. Potential exposure to the chemical in the product

3. Minimal potential for environmental releases
   - Highly regulated
   - Closed loop recycling
     - Today’s recycling of LABs is an established, economic process
     - >93% of a LAB is available for recycling
     - >85% of a typical LAB is comprised of material that is recycled from older batteries.
     - Achieved 99% recovery rate between 2009-2013

Primary Factor Considered:

2. Potential for exposure to that chemical to cause significant or widespread adverse impacts to human health or the environment

Risk of adverse impacts dependent on both exposure and hazard

- Consumer exposure not expected during typical product use scenarios, minimizing risk of health impacts

- Lead batteries have low lifecycle environmental impact among all battery technologies with low emission of carbon dioxide, particulate matter, nitrogen oxides, sulphur oxides and volatile organic compounds, as well as very low production energy

Secondary Factors Considered

DTSC considers three secondary factors when identifying a product-chemical combination:

1. The extent to which existing state and federal regulations may be addressing these concerns

2. Whether the listing would meaningfully enhance protection of public health and the environment

3. Availability of safer alternatives that are functionally acceptable, technically feasible, and economically feasible

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Secondary Factor Considered:

1. The extent to which existing state and federal regulations may be addressing these concerns

- SCP Regulation states that it should not duplicate federal or state regulations without conferring additional public health or environmental protection benefit

- Many federal and state laws regulate LABs

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Secondary Factor Considered:

1. The extent to which existing state and federal regulations may be addressing these concerns

Many federal and state laws regulate LABs

- State: Every single state has some form of regulation on lead-acid batteries that cover the disposal, duties of retailers and wholesalers, preparation and distribution of these products
- Federal: EPA's Resource Conservation and Recovery Act (RCRA) hazardous waste transboundary shipment regulations
- International: Export notices and guidance have been issued and continue to be updated for all Organisation for Economic Cooperation and Development (OECD) and non-OECD countries. The EPA has employed these regulations to safely transport lead-acid batteries across state and international boundaries

Secondary Factor Considered:

2. Whether the listing would meaningfully enhance protection of public health and the environment

- Listing LABs as a Priority Product would not meaningfully enhance protection of public health and the environment because this action would be redundant to other current
    - As discussed earlier, a variety of state and federal Agencies are already evaluating LABs
    - This analysis has already been done in Europe
    - Auto manufacturers and battery manufacturers are already aggressively pursuing alternatives

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Secondary Factor Considered:

2. Whether the listing would meaningfully enhance protection of public health and the environment

This analysis has already been done in Europe

- Background
- EU Evaluations
- Exemptions Not Permanent – Periodic Review

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Secondary Factor Considered:

2. Whether the listing would meaningfully enhance protection of public health and the environment

This analysis has already been done in Europe

- Background
  - End-of-Life Vehicle ("ELV") Directive 2000/53/EC
  - Adopted by the European Commission in September 2000
  - Objective of limiting waste from ELVs and their components
  - Restricts use of lead, and other materials, but provides for exemptions
  - Strictly an availability of alternatives analysis – no consideration of social or economic impacts
  - Manufacturers, importers, and distributors must provide systems to collect ELVs and reuse or recycle parts
  - EU countries report on implementation of the Directive to the European Commission every three years

Secondary Factor Considered:

2. Whether the listing would meaningfully enhance protection of public health and the environment

This analysis has already been done in Europe

- EU Evaluations
  - EU already conducted an evaluation in 2014 -2016.
  - 2016 - Oeko Institut report finds lead batteries have no replacement, are still essential, and recommends continuance of exemption
  - Exemptions continue to be issued
  - A new evaluation is scheduled by the EU Commission for 2021 to clarify if future alternatives for volume production will be available.

Secondary Factor Considered:

2. Whether the listing would meaningfully enhance protection of public health and the environment

This analysis has already been done in Europe

- Exemptions Not Permanent – Periodic Review
  - Annex II of the Directive provides relief for a variety of articles and compounds including lead and lead compounds in components
  - Lead batteries have been exempt since adoption of the Directive in 2000.
  - Annex II currently on eighth revision
  - Reviewed in 2002, 2005, 2008, 2010, 2011, 2013, 2016

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Secondary Factor Considered:

2. Whether the listing would meaningfully enhance protection of public health and the environment

Auto Manufacturers and Battery Manufacturers Are Already Aggressively Pursuing Alternatives

- Automakers should be supported in its efforts to find alternatives

- Industry resources should continue to be used to pursue innovation and new technology instead of used for complying with a regulation that seeks the same result

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Secondary Factor Considered:

3. Availability of safer alternatives that are functionally acceptable, technically feasible, and economically feasible

Although automakers have made significant innovation and progress in alternative technologies, lead-based batteries are still the only technologically viable mass-market option currently available for conventional vehicles, as well as for start-stop and micro-hybrid vehicles.

Alternative technologies would need to match traditional batteries in terms of reliability, safety, cost and other factors.

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Secondary Factor Considered:

3. Availability of safer alternatives that are functionally acceptable, technically feasible, and economically feasible

Functionally Acceptable / Technically Feasible

- Development Time
- Safety Issues
- Board-Net Voltage
- Avoiding Regrettable Substitutions
- Replacement Parts
- Implementation Time

Secondary Factor Considered:

3. Availability of safer alternatives that are functionally acceptable, technically feasible, and economically feasible

Functionally Acceptable / Technically Feasible

- Development Time
  - Between 54-80 months or more
  - Depends on the types of alternative materials available
  - Depends on the type and function of the component
  - The charging structure, charging rate, and charging current are all very different from a LAB vs a Li-Ion battery, and is also dependent on a vehicle's final options
  - Potential aftermarket replacement batteries may or may not contain a "charge controller" and could be of poor quality or don't exist in a Li-Ion replacement battery which would impact its functionality with a vehicle's wiring harness
  - Each OEM develops a unique Li-Ion battery to function in its specific vehicle lines and are not transferrable across model lines or across OEMs

Secondary Factor Considered:

3. Availability of safer alternatives that are functionally acceptable, technically feasible, and economically feasible

Functionally Acceptable / Technically Feasible

- Safety Issues
  - Must comply with a variety of state and federal laws and regulations, including NHTSA, EPA, and others
  - Extensive testing required
  - Must have reliable performance
  - Packaging Locations

Secondary Factor Considered:

3. Availability of safer alternatives that are functionally acceptable, technically feasible, and economically feasible

Functionally Acceptable / Technically Feasible

- Safety Issues
  - Must comply with a variety of state and federal laws and regulations, including NHTSA, EPA, and others
    - Increased OBD II diagnostic requirements by CA ARB. Currently, no existing OBD-compliant 12V BMS expertise at suppliers, and 12V compliance can not be copied-and-pasted from higher voltages.

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Secondary Factor Considered:

3. Availability of safer alternatives that are functionally acceptable, technically feasible, and economically feasible

Functionally Acceptable / Technically Feasible

- Safety Issues
  - Extensive testing required
    - Numerous testing standards must be met, including SAE and IEC that set safety testing standards such as SAE J2464, J2929, UL 2054. But existing standards are for drivetrain batteries. No safety or performance standard yet approved for lithium starter batteries.
    - Mechanical, electrical, environmental and chemical tests are called for by various standards and regulations in the US and abroad
    - On component and vehicle level
    - Vehicle crash tests must be performed
    - Not clear if non-OEM aftermarket Li-Ion batteries have been "certified" to all vehicle crash tests with documented safety certification reports.

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Secondary Factor Considered:

3. Availability of safer alternatives that are functionally acceptable, technically feasible, and economically feasible

Functionally Acceptable / Technically Feasible

- Safety Issues
  - Must have reliable performance at low and elevated temperatures
    - Lead batteries have an unrivaled and robust cranking charging ability in cold climate—with no associated safety issues.
      - Li-plating is considered a safety concern with charging at low temps
    - LABs have a lower freezing point than most Li-Ion batteries that use EMC-based electrolytes.
    - Li-ion batteries may require thermal solutions for ultra-cold or ultra-hot environments, as can be found in automotive uses.
    - Currently, very limited number of suppliers have a cost-effective Li-Ion technology capable of cold-cranking a vehicle to SAE standard.

Secondary Factor Considered:

3. Availability of safer alternatives that are functionally acceptable, technically feasible, and economically feasible

Functionally Acceptable / Technically Feasible

- Safety Issues
  - Packaging Locations
    - Approximately 50% of batteries are underhood across the industry
    - Underhood Li-Ion batteries will require a yet-to-be developed fail-safe thermal solution, and possibly crash solutions

Secondary Factor Considered:

3. Availability of safer alternatives that are functionally acceptable, technically feasible, and economically feasible

Functionally Acceptable / Technically Feasible

- Board Net Voltage
  - Current automotive components have been developed for a reliable and consistent 12V power supply; therefore changing a vehicle's system voltage could require redesigning
    - Generator, engine controllers, and potentially many other devices
    - Control algorithms, entry/exit points, and interfaces between components with regard to regulations mandated by other Governmental entities (e.g., EPA, CARB, etc.)

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Secondary Factor Considered:

3. Availability of safer alternatives that are functionally acceptable, technically feasible, and economically feasible

Functionally Acceptable / Technically Feasible

- Avoiding Regrettable Substitutions
  - Moving forward prematurely before the technology is mature, ready for mass production, and the hazards and risks of end of life vehicle are well understood, creates a good chance of becoming a regrettable substitution and could be worse in the long run.
  - A serious alternative analysis would require extensive market experience with pilot and lighthouse applications over at least one product cycle (approximately six to ten years). There is currently little experience available.

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Secondary Factor Considered:

3. Availability of safer alternatives that are functionally acceptable, technically feasible, and economically feasible

Functionally Acceptable / Technically Feasible

- Replacement Parts
  - The average age of autos on the road today is over 11 years
  - Required to maintain replacement part availability for 15 years
  - OEM-unique Battery Management System communications for Li-Ion limit aftermarket distribution efficiency (including CA ARB "right to repair" requirements would be inhibited)
  - “Drop-In”” Replacements may not be feasible for existing vehicle designs

Secondary Factor Considered:

3. Availability of safer alternatives that are functionally acceptable, technically feasible, and economically feasible

Functionally Acceptable / Technically Feasible

- Replacement Parts
  - "Drop-In"" Replacements may not be feasible for existing vehicle designs
    - Vehicle and electrical architecture and design standards closely linked to lead battery functionality: Lead batteries typically placed within the engine bay. This is a high-heat area and a crash "crumple zone."
    - Unclear whether lithium chemistries can be designed, tested, and certified to perform similarly in the same locations. May not be possible for existing vehicle designs, especially lower cost vehicles for many years.
    - A mass-market, drop-in solution would require time consuming development on a number of issues such as cold cranking-time, battery management, and discharge characteristics.

Secondary Factor Considered:

3. Availability of safer alternatives that are functionally acceptable, technically feasible, and economically feasible

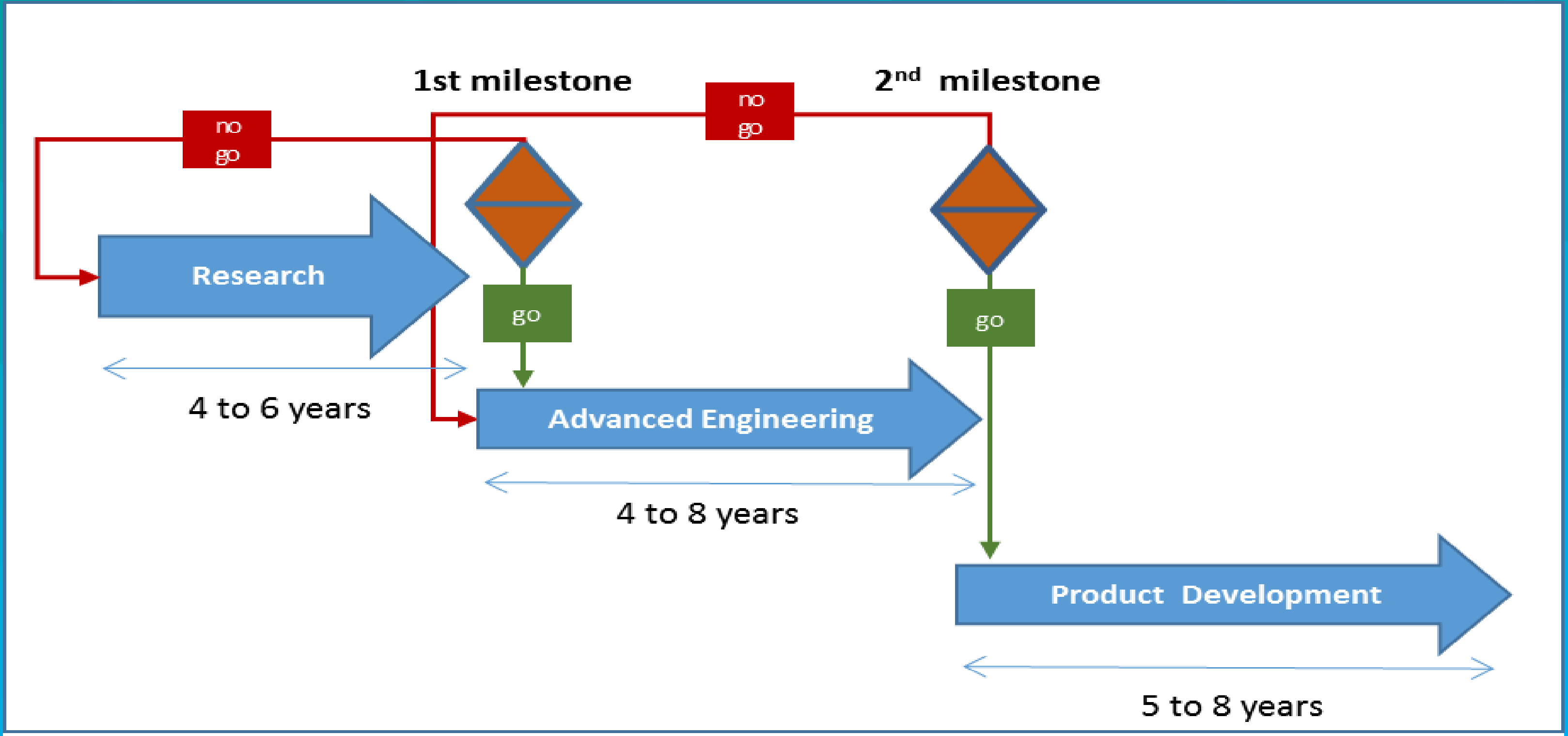
Functionally Acceptable / Technically Feasible

- Implementation Time – Conservative Estimate is Over Ten Years
  - Manufacturing Infrastructure
  - Employees would need training
  - Sufficient financial investment required
  - Alternatives need sufficient change-over periods
  - Alternative Technology Resource Issues
  - OEMs use staggered vehicle introduction schedules

Secondary Factor Considered:

3. Availability of safer alternatives that are functionally acceptable, technically feasible, and economically feasible

Steps Before Alternative Battery Meets Mass Market OEM Requirements



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Secondary Factor Considered:

3. Availability of safer alternatives that are functionally acceptable, technically feasible, and economically feasible

Economically Feasible

- Implementation Costs
- Battery Costs
- Consumer Costs

Secondary Factor Considered:

3. Availability of safer alternatives that are functionally acceptable, technically feasible, and economically feasible

Economically Feasible

- Implementation Costs
  - Manufacturing Infrastructure
  - Vehicle redesign costs

Secondary Factor Considered:

3. Availability of safer alternatives that are functionally acceptable, technically feasible, and economically feasible

Economically Feasible

- Implementation Costs
  - Manufacturing Infrastructure
    - Existing plants may need to be completely replaced or existing factories may need to be re-tooled to a new purpose
    - Employees could need training

Secondary Factor Considered:

3. Availability of safer alternatives that are functionally acceptable, technically feasible, and economically feasible

Economically Feasible

- Implementation Costs
  - Vehicle redesign costs
    - Need for battery management system drives new communication and control requirements, and additional shielding and housing increase system level costs
    - Many vehicles would need to be redesigned to move lead battery out of engine compartment in order to place Li-Ion into the passenger compartment due to engine heat.
    - Possibly two sets of vehicles – California and the rest of the US

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Secondary Factor Considered:

3. Availability of safer alternatives that are functionally acceptable, technically feasible, and economically feasible

Economically Feasible

- Battery Costs
  - Not possible to assess cost on a per-vehicle basis
  - Examples of other cost considerations

Secondary Factor Considered:

3. Availability of safer alternatives that are functionally acceptable, technically feasible, and economically feasible

Economically Feasible

- Battery Costs
  - Not possible to assess cost on a per-vehicle basis
    - No data identified on the use of alternative battery chemistries in conventional vehicle applications (e.g. starting the engine, running the lights, etc.)
    - There is no single battery chemistry that addresses all issues – certain batteries work in certain applications.

Cost Comparison for Battery Chemistries Across Different Vehicle Classes

Vehicle Class	Battery Chemistry		
	Lead-acid	Nickel	Lithium-ion
Class 1 Conventional	50-150 €/kWh 6-18 €/kW	700-1400 €/kWh 90-180 €/Kw	600-1200 €/kWh 118-236 €/kW
Class 2 Hybrid	100-200 €/kWh 10-20 €/kW	800-1400 €/kWh 27-47 €/kW	800-1200 €/kWh 30-75 €/kW
Class 3 EV	100-250 €/kWh 10-25 €/kW	400-500 €/kWh 910-1140 €/kW	300-450 €/kWh 100-200 €/kW
Class 4 PHEV	(not provided)	(not provided)	800-1200 €/kWh 30-75 €/kW

adapted from Okeo Institut 2016
http://ec.europa.eu/environment/waste/elv/pdf/20160414_ELV_Final_Gen_Ex_2c___Ex_3_Ex_5.pdf
accessed November 1, 2017

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Secondary Factor Considered:

3. Availability of safer alternatives that are functionally acceptable, technically feasible, and economically feasible

Economically Feasible

- Battery Costs
    - Examples of other cost considerations
        - Robust thermal solutions for packaging a Li-Ion underhood is over-and-above battery premium costs
        - Possible instability of raw materials cost
        - Full life cycle costs for Li Ion not known

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Economically Feasible

- Consumer Costs
  - Total increase in cost of new vehicles unknown
  - Relatively significant up-front costs for consumers
  - Total cost of ownership of older vehicles

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